# A Classification of the Fundamental 3+1+1 Forces

**S. Afsar Abbas**
Centre for Theoretical Physics
JMI, New Delhi - 110025, India
(e-mail : afsar.ctp@jmi.ac.in)

**Abstract**

The Dark Energy problem is forcing us to re-examine our models and our understanding of relativity and space-time. The Standard Model of particle physics and its extensions are already in crisis. Having failed so far to include gravity in a proper unified framework, these are now faced with an additional unwanted fifth force of repulsion. How does one understand this 3+1+1 fundamental force dilemma? Quite clearly this points to a limitation of our present understanding and demands extension of our theoretical framework. To be able to go beyond these limitations, here we introduce a novel idea of the Fundamental Forces. This allows us to perceive the General Theory of Relativity and Einstein's Equation from a different perspective. This will give us an additional and an all-encompassing way of classifying these five fundamental forces in a consistent manner. In addition to providing us with an improved understanding of space and time, it will be shown how it leads to a resolution of the Dark Energy problem.

Dark Energy is certainly the most puzzling problem in physics and astronomy today [1]. All kind of proposals, mostly ad-hoc in nature, to solve the problem, are being put forward. But we are nowhere near a resolution of the issues involved.

So far all our understanding of nature has been successfully described within the Standard Model (SM) of particle physics. Whatever was not accessible to it, has been explained in terms of various theoretical extensions of the SM. All this was done in terms of an understanding that there are four fundamental forces. Three of these are gauge forces and the fourth one, that of gravity, it is believed, shall "soon" be incorporated in a unified whole as some kind of quantized gauge theory. This "soon" has been dogging us for several decades. The problem becomes more confusing in that there always remains a clear possibility that gravity, at a fundamental level, may be a different kind of force altogether and may not be quantized at all, and in which case its unification with the other three forces will have to be seen differently. The fact that one has not been able to achieve this so called unification of the four forces so far, we are thus justified in breaking this so called four force problem as actually being of the nature of a 3+1 force problem.

Given the above situation, no one expected and no one wanted, yet another new fundamental "force" to spring up. But there it is - the new force of repulsion of galaxies [1], call it RF (Repulsive Force)!

One question that arises immediately is, as to the nature of this RF. Is it a simply a gauge force like the other three and then the force problem is of the 4+1 kind; or is it fundamentally of the gravity kind and in which case the force problem is that of 3+2 kind; or is it different from all these and in which case it is 3+1+1 kind?

To understand this, let us look at the Einstein's Equation. Harvey and Schucking [2] correcting for Einstein's error in understanding the role of the cosmological term $\lambda$, have derived the most general equation of motion to be

$$G_{\mu\nu} + \lambda g_{\mu\nu} = 8\pi G \langle \phi | T_{\mu\nu} | \phi \rangle \tag{1}$$

They showed that the Cosmological Constant $\lambda$ above provides a new repulsive force proportional to mass m, repelling every particle of mass m with a force

$$F = mc^2 \frac{\lambda}{3} x \tag{2}$$

Recent data [1] on $\lambda$ is what leads to the crisis of Dark Energy.

The situation is akin to the discovery of the muon, when people were quite happy and contended with only the electron and when I. I. Rabi in puzzlement asked, "who ordered it?" We too can paraphrase Rabi by asking, "Who ordered this fifth force?" The discovery of muon forced scientists to extend their theoretical framework significantly. No patch-up work, but a genuine attempt to include this new force in a fundamental and consistent framework of our understanding of nature.

It may be remarked that the concept of a so called fifth force has been there for quite sometime. Extensions of Einstein's GTR, like for example Brans-Dicke theory, necessarily have an extra fifth force, in which case the RF may belong to the 3+2 or 3+1+1 classification. Higher dimentional Kaluza-Klein kind of theories, supersymmetric theories, superstring theories etc also predict the fifth fundamental force of the Yukawa kind and in which case it will very likely belong to the 4+1 kind. It is not clear that the new RF is this putative fifth force [1,3]. In fact this theoretical fifth force is incompatible with overall cosmological framework [1,3]. Just because the word "fifth" force has been usurped by the other models, does not mean that the actual empirical fifth RF is of their kind. So minimal conclusion would be that with the new RF, the force problem is per se of the 3+1+1 kind.

Here we wish to understand the "force" nature of the new problem. To do so we introduce a new concept of the "Universal Force". It was first proposed by Hans Reichenbach [4]. It is a genuine scientific concept, which having been proposed in a book called "philosophical", has unfortunately not been accessible to physicists by and large. Reichenbach's "lost" work on the three-valued logic for quantum mechanics, in recent years, has found its way in physics literature. The concept of the "universal Force" deserves it, actually more so! Rudolf Carnap in the Introduction of Reichenbach's book [4] called the concept of the Universal Forces, " ... of great interest for the methodology of physics but what has so far not received the attention it deserves". In this paper we shall try to rectify for this failure of appreciating the concept of the Universal Forces - albeit in a somewhat altered and improved manner.

Reichenbach defines two kind of forces - Differential Forces and Universal Forces. It may be pointed out that the term "force" here should not be

taken strictly as defined in physics but in a broad and general framework. In fact Carnap has suggested that the term "effect" instead of "force' would better serve the purpose [4] and which allows it be used in different frameworks. Hence to conform with the accepted practice, though in this paper we shall continue to use the term "Universal Force" the reader may do well to remember that what we really mean is "Universal Effect".

One calls a force Differential if it acts differently on different substances. It is called Universal if it is quantitatively the same for all the substances [4,5]. If we heat a rod of initial length $l_0$ from initial temperature $T_0$ to temperature T then its length is given as

$$l = l_0[1 + \beta(T - T_0)] \tag{3}$$

where $\beta$ the coefficient for thermal expansion is different for different materials. Hence this is a Differential Force. Now the correction factor due to the influence of gravitation on the length of the rod is

$$l = l_0[1 - C\frac{m}{r}cos^2\phi] \tag{4}$$

Here the rod is placed at a distance r from sun whose mass is m and $\phi$ is the angle of the rod with respect to the the line sun to rod. C is a universal constant ( in CGS unit C= 3.7 x $10^{-29}$ ). As this acts in the same manner for any material of mass m, gravity is a Universal Force as per the above definition.

Reichenbach also gives a general definition of the Universal Forces [4,p 12] as: (1) affecting all the materials in the same manner and (2) there are no insulating walls against it. We saw above that gravity is such a force,

Indeed gravity is a Universal Force par excellence. It affects all matter in the same manner. The equality of the gravitational and inertial masses is what ensures this physically. If the gravitational and inertial masses were not found to be equal, then one would not have been able to visualize of the paths of freely falling mass points as geodesics in the four dimentional space-time. In that case different geodesics would have resulted from different materials of mass points [4].

Therefore the universal effect of gravitation on different kinds of measuring instruments is to define a single geometry for all of them. Viewed this way, one may say that gravity is geometerized. "It is not theory of gravitation that becomes geometry, but it is geometry that becomes the experience of the

gravitational field" [4, p 256]. Why does the planet follow the curved path? Not because it is acted upon by a force but because the curved space-time manifold leaves it with no other choice!

So as per Einstein's theory of relativity, one does not speak of a change produced by the gravitational field in the measuring instruments, but regard the measuring instruments as free from any deforming forces. Gravity being a Universal Force, in the Einstein's Theory of Relativity, it basically disappears and is replaced by geometry.

In fact Reichenbach [4, p 22] shows how one can give a consistent definition of a rigid rod - the same rigid rods which are needed in relativity to measure all lengths. "Rigid rods are solid bodies which are not affected by Differential Forces, or concerning which the influence of Differential Forces has been eliminated by corrections; Universal Forces are disregarded. We do not neglect Universal Forces. We set them to zero by definition. Without such a rule a rigid body cannot be defined." In fact this rule also helps in defining a closed system as well.

All this was formalized in terms of a theorem by Reichenbach [4, p 33]

**THEOREM** $\theta$ :

Given the geometry $G^0$ to which the measuring instruments conform, we can imagine a Universal Force F which affects the instruments in such a way that the actual geometry is an arbitrary geometry $G$, while the observed deviation from $G$ is due to universal deformation of the measuring instruments."

$$G^0 + F = G \tag{5}$$

Hence only the combination $G^0+F$ is testable. As per Reichenbach's principle one prefers the theory wherein we put F=0. If we accept Reichenbach principle of putting the Universal Force of gravity to zero, then the arbitrariness in the choice of the measuring procedure is avoided and the question of the geometrical structure of the physical space has a unique answer determined by physical measurement. It is this principle which Carnap praises highly [5, p 171], " Whenever there is a system of physics in which a certain universal effect is asserted by a law that specifies under what conditions in what amount the effect occurs, then the theory should be transformed so that

the amount of effect would be reduced to zero. This is what Einstein did in regard to contraction and expansion of bodies in gravitational field." The left hand side of Einstein's equation (below) gives the relevant non-Euclidean geometry

$$G_{\mu\nu} = 8\pi G\langle\phi|T_{\mu\nu}|\phi\rangle \tag{6}$$

(Note that we suppress $\lambda$ here). In the case of gravity, and in as much as Einstein's Theory of Relativity has been well tested experimentally, we treat the above concept as well placed empirically. But from this single success Reichenbach generalizes this as a fundamental principle for all cases where Universal forces may arise. As Carnap states [5, p 171], " Whenever universal effects are found in physics, Reichenbach maintained that it is always possible to eliminate them by suitable transformation of theory; such a transformation should be made because of the overall simplicity that would result. This is a useful general principle, deserving more attention than it has received. It applies not only to relativity theory, but also to situations that may arise in the future in which other universal effects may be observed. Without the adoption of this rule there is no way to give unique answer to the question - what is the structure of space?".

As such Reichenbach goes ahead and tries to apply this principle of elimination of Universal Forces to another universal effect that he finds and which arises from considerations of topology ( as an additional consideration over and above that of geometry ) of space-time of the universe.

The Theorem $\theta$ is limited to talking about the geometry of space-time only. It does not take account of specific topological issues that may arise. To take account of topology of the space-time we shall have to extend the said theorem appropriately.

What would one experience if space had different topological properties. To make the point home Reichenbach considers a torus-space [4, p 63]. This is quite detailed and extensive. However for the purpose of simplifying the and shortening the discussion here we shall talk of a two dimensional being who lives on the surface of a sphere. His measurements tell him so. But in spite of this he insists that he lives on a plane. He may actually do so as per our discussion above if he confines himself to metrical relations only. With an appropriate Universal Force he can he can justify living on a plane. But the surface of a sphere is topologically different from that of a plane. On a

sphere if he starts at a point X and goes on a world tour he may come back to the same point X. But this is impossible on a plane. And hence to account for coming back to the "same point" he has to maintain that on the plane he actually has come back to a different point Y - which though is identical to X in all other respects. One option for him is to accept that he is actually living on a sphere. However if he still wants to maintain his position that he is living on a plane then he has to explain as to how point Y is physically identical to point X in spite of the fact that X and Y are different and distinct points of space. Indeed he can do so by visualizing a fictitious force as an effect of some kind of "pre-established harmony" [4, p 65] by proposing that everything that occurs at X also occurs at the point Y. As it would affect all matter in the same manner this corresponds to a Universal Force/Effect as per Reichenbach's definition.

This interdependence of corresponding points which is essential in this "pre-established" harmony cannot be interpreted as ordinary causality, as it does not require ordinary time to transmit it and also does not spread continuously through intervening space. Hence there is no mysterious causal connection between the points X and point Y. Thus this necessarily entails proposing a "causal anomaly" [4, p 65]. In short connecting different topologies through a fictitious Universal Effect of "pre-established harmony" necessarily calls for introduction of "causal anomalies". Call this new hypothesize Universal Force as A and the Theorem $\theta$ be extended to read

$$G^0 + F + A = \mathbf{G} \tag{7}$$

where on the right had side we have given a different capital $\mathbf{G}$ which reduces to $G$ of the original Theorem $\theta$ when A is set equal to zero.

Now as per Reichenbach's law of preferring that physical reality wherein all Universal Forces are put to zero, he advocates of putting A to zero. He pointed out that this has the advantage of retaining physical "causality " in our science.

However, as the said 'causal anomaly" is of topological origin we cannot be sure in what manner it will manifest itself physically. In addition will not the Universal Force/Effect of "pre-established harmony" compensate for it in some manner? So what one is saying is that it is possible that Reichenbach was wrong in putting all Universal Forces to zero. It was fine to put F to zero, which allowed us to define a truly "rigid" rod and which let to a

geometrical interpretation of gravity in a unique manner. But in the case of this new topological Universal Force we really do not know enough and let us not be governed by any theoretical prejudice and let the Nature decide as to what is happening. So to say, let us look at modern cosmology to see if it is throwing up any new Universal Forces which may be identified with our "pre-established harmony" here.

Not known to Reichenbach at his time, but now known to us, and as discussed above, there is indeed another "Universal Force" of repulsion RF. It is universal as it acts in the same manner on all bodies of mass m. This new fifth fundamental force, which is a puzzle for the SM and its putative extensions, is but a natural ally of gravity in being of universal character.

Quite clearly this repulsive force is a new Universal Force as per our definition and hence conforms to the "pre-established harmony" aspect of the "causal anomaly". Thus we see that indeed as per the recent data on accelerating universe we have stumbled upon this new Universal Force which is of topological origin. Hence the source of dark energy is due to "causal anomaly" arising from the unique topological structure of our universe. This solves the mystery of the origin of Dark Energy.

So we would like to emphasize that it is the accelerating universe ( and hence the Dark Energy ) which is forcing us to accept the incorporation of this "causal anomaly" of topological origin. Implications of this new concept in physics have now to be explored.

We know that the surface's values which do not change with deformation are called "topology" of the surface. A surface's "geometry" consists of those properties which do change with deformation of the surface. Viewed this way, topology and geometry are complementary properties of space-time. Indeed this is how gravity ( related to geometry ) and the new repulsive-force ( related to topology) arise as two fundamental and complementary Universal Forces.

Why one is attractive and the other repulsive, is something that may be part of this complementarity. We do not understand that yet, but the very fact that they are both of universal character should allow us to understand them better in future.

So as per this new classification, there are three well known gauge forces and two universal forces - that of gravity and the new one of repulsion. However, this has an advantage that it points to a basic similarity between the two - gravity and repulsive-force, which is not apparent in the canonical

way of adding up the fifth force in an ad-hoc manner. Hence as per the definition above, the forces should be classified as 3+2 kind. Clearly this is providing us with an understanding which may help us in the present puzzling scenario. It is allowing us to understand the nature of this new RF without contradicting anything known today.

One would like to ask as to in what other manner, incorporation of this new "causal anomaly", may help us in understanding Nature better? Will it provide new perspectives as answers to quantum mechanical puzzles of quantum jumps, non-locality etc. These are open questions to be tackled in future.

In the early twentieth century, one knew of only two fundamental forces - the gravitational and the electromagnetic. Having obtained his equation of motion in GTR, Einstein tried to unify electromagnetism within the same geometrical framework. Others like Weyl also tried to do so. Kaluza's higher dimentional idea was aimed at the same target. With hindsight we know now that they failed because they did not take account of the strong and the weak forces. We have also learned that these two along with electromagnetic are gauge forces. And also as discussed above, gravity has not fallen in line as of now. Could it be that we have failed to get a Theory of Everything so far, as like earlier, we were not aware of all the forces. We should re-examine our understanding of what we mean by force, expand out in proper direction an see if there are other ways of looking at a "force" different from the canonical manner of looking at it and which we teach to our undergraduates. Quite clearly we have no clue as to why there are five (3+1+1) forces? Can we be sure that this is it and no more fundamental forces will make their presence felt in the future. If they do, then present accepted point of view will be at a loss to account for it. But the UF idea presented above will naturally incorporate it. This is the power of the UF idea. In this paper we have pointed out a very fruitful approach which not only allows us to look at the new RF in a new manner, but also points to a new a direction on Dark Energy as well.

Niels Bohr always rued that a proper understanding of quantum mechanics was too much shackled by language. Perhaps he was right. The shackles put by the canonical way of looking at the new unwanted fifth force may be the cause of present confusion. The new framework of Universal Forces is allowing us to expand our vocabulary and understanding and is hopefully making us more competent in tackling the new puzzles of the fifth force.

## REFERENCES


1. E J Copeland, M Sami and S Tsujikawa, "Dynamics of Dark Energy" *Int J Mod Phys*, **D 15** (2006) 1753-1936

2. A Harvey and E Schucking, "Einstein's mistake and the cosmological constant", *Am J Phys*, **68** (2000) 723-727

3. E I Guendelmann and A B Kaganowich, "Dark Energy and the Fifth Force Problem", *J Phys*, **A 41** (2008) 164053

4. H Reichenbach, "The philosophy of space and time", Dover, New York (1957) (Original German edition in 1928)

5. R Carnap, "An introduction to the philosophy of science", Basic Books, New York (1966)